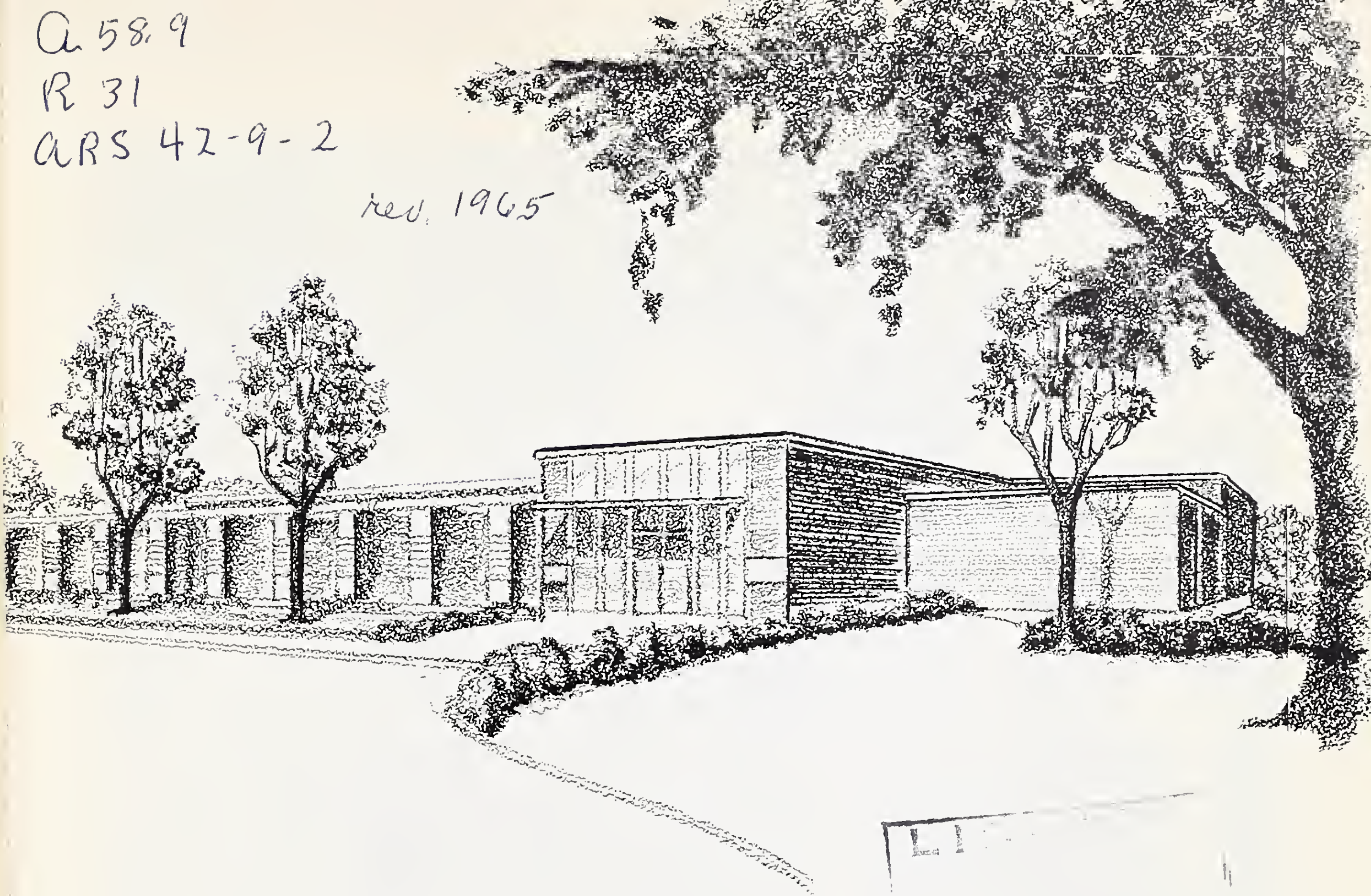

THE NATIONAL TILLAGE MACHINERY LABORATORY

Auburn, Alabama

U. S. DEPARTMENT OF AGRICULTURE / AGRICULTURAL RESEARCH SERVICE
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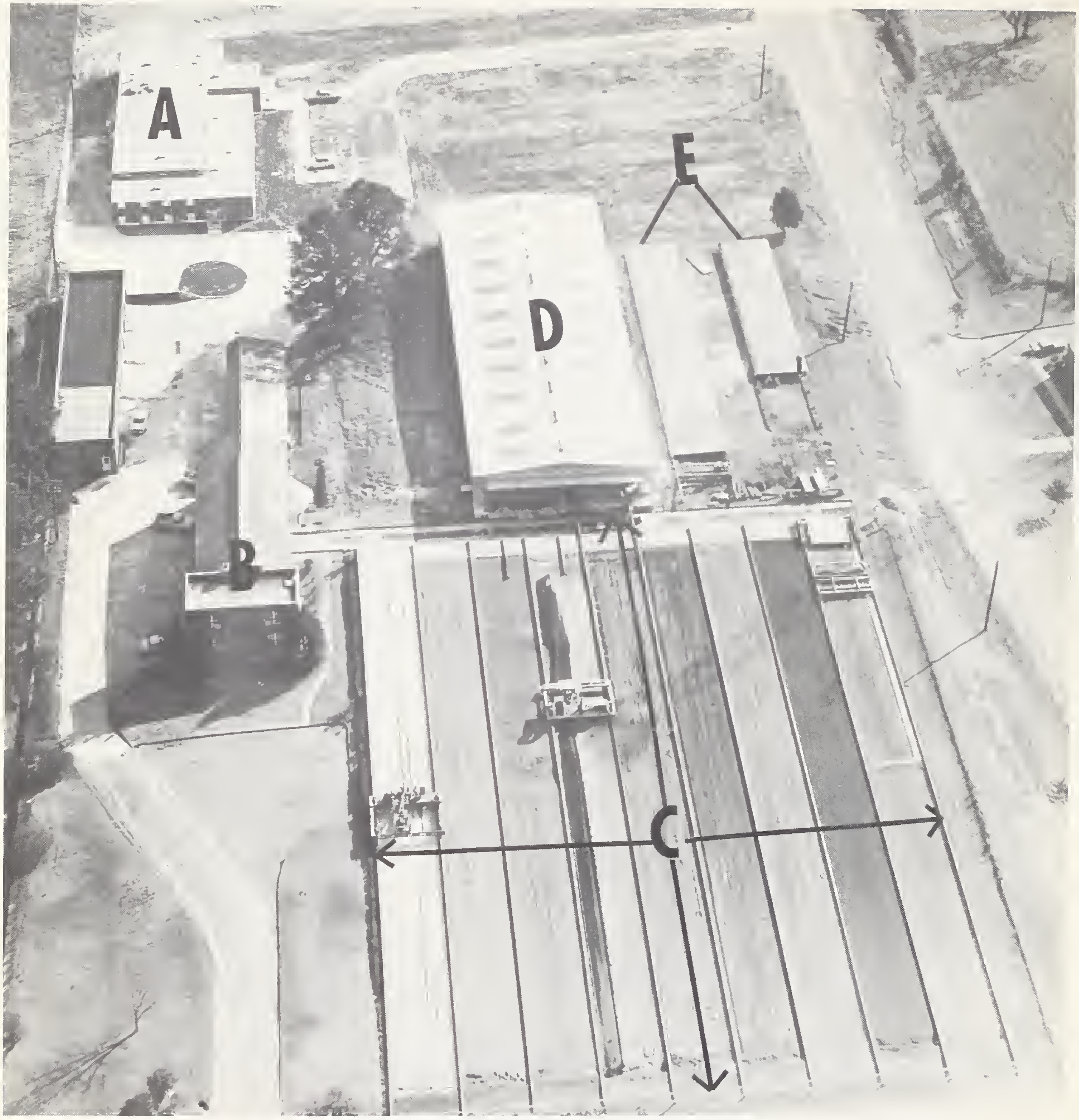


Air view of the National Tillage Machinery Laboratory. (A) New office-laboratory building. (B) Original office-laboratory building. (C) Outdoor soil bins. (D) New building housing two full-scale soil bins. (E) Cover cars for protecting soil bins until tests can be completed. (NTML photo-M-10,171i)

Cover: Sketch of new office-laboratory building at the National Tillage Machinery Laboratory, Auburn, Ala.

THE NATIONAL TILLAGE MACHINERY LABORATORY
Auburn, Alabama

Each year, in the United States, more than 250 billion tons of soil are turned or stirred in the production of food and fiber. This is enough soil to make a ridge 100 feet high and 1 mile wide from New York to San Francisco. Much of this soil is stirred several times by tillage and cultivation operations. In addition to the soil that is moved for the production of crops, additional billions of tons are moved annually in the construction of highways and buildings, and in land forming, mining, and military operations.

Soil tillage is probably the world's largest materials handling operation. Yet, most of the tillage and soil-moving implements now in use have been developed on the basis of field experience rather than scientific knowledge of the relationships between soil characteristics and forces that would influence equipment design. As a result, tillage and other types of field equipment frequently use an excessive amount of power, or they are not as effective as they should be. Their use over a long period may result in excessive compaction or other damage to the physical character of the soil.

In all soil-moving and other off-the-road operations, tires or tracks provide, or control, forward movement of the equipment. In these operations, the power lost through tires is often 50 percent or more. An estimated fuel equivalent of 500 million gallons of gasoline could be saved each year with a 10-percent improvement in traction efficiency. Tire slippage also results in excessive tire wear.

These and similar problems are of direct concern to the National Tillage Machinery Laboratory, where scientific research is underway to determine and study laws that govern the reaction of soil to forces. Research at the Laboratory is furnishing information that will aid in more efficient use of existing equipment, and that can be applied in the design of new and improved equipment.

THE LABORATORY

History and Purpose

The National Tillage Machinery Laboratory is a part of the Agricultural Engineering Research Division of the Agricultural Research Service, U.S. Department of Agriculture. It is located at Auburn, Ala., on a 6.3-acre site within the campus of Auburn University, which was donated to the Federal Government by the University.

The Laboratory, established in 1935, was set up to undertake research related to tillage practices and machine use in cotton production. However, since many of the tillage machinery problems in cotton production were common to other crops, the scope of research was broadened to include all types of tillage machinery and practices. Traction and transport research, which also involves soil physical reactions and requires similar facilities, was part of the original program.

A unique feature of the Laboratory is the soil bins, which have eliminated many of the difficulties encountered in previous tillage research. The bins contain a variety of soils, making possible studies that previously could not be carried out without a great deal of travel. In field studies it was often necessary to wait until natural forces produced a soil condition that was desired for specific studies. In the bins, which are large enough to make full-scale studies of tillage tools, tires, and tracks, the soils can be fitted with special soils-handling machinery. In this manner, the soil in the bins can be made more uniform than found under field conditions. This is highly desirable in determining comparative force measurements on different shaped im-

plements. Also, different soil conditions can be produced, and a given soil condition can be closely approximated. The surface elevation can be controlled from accurately set rails, allowing the depth of tillage to be controlled within very close limits. This accuracy has not been attained in field studies. The soil bins with special equipment allow only the implement being studied to come in contact with the soil, so that the studies are not complicated by wheel tracks or other traffic compaction. More accurate instrumentation can be carried on the bin equipment than is usually available on conventional field research equipment.

Facilities Expanded

In June of 1960, the Congress of the United States appropriated funds for expanded physical facilities. With these funds, a new office-laboratory building and a building containing two soil bins were constructed.

Staff

The professional staff is presently composed of nine agricultural engineers and two soil scientists. With supporting personnel, the total Laboratory staff is 25.

WORK OF THE LABORATORY

Research Program

The program of research is in the area of soil-machinery relationships. While the main purpose of the Laboratory is to conduct research that will contribute information for better design and use of tillage tools, and traction and transport devices for crop production, much of the basic information obtained will also apply to other soil-moving equipment or off-the-road vehicles.

Some specific long-term research objectives of the Laboratory are listed below. Comprehensive work has been undertaken in only a few of the areas.

- Determine the components of forces tillage tools exert on the soil so that the design of tools, hitches, engines, and tractors can be facilitated.
- Study the influence of variations in tillage tool design factors and the methods of use, i.e., working depth and speed of operation, on power requirements and tilth created in different soil conditions. Then determine the minimum amount of soil manipulation necessary to produce the desired tilth.
- Determine new and more effective methods of applying forces to soil so that the minimum amount of energy may be applied to produce soil tilth, handle soil, or secure traction transport.
- Study the physical factors which influence the susceptibility of the soil to compaction and the resistance to pulverization, cutting, shearing, or movement.
- Study the influence of variations in tractive/transport device design factors and their methods of use, including tire geometry, materials, construction, wheel slip, tandem wheel arrangement, and ballast, on the tractive and transport capabilities in different soil conditions.
- Study the abrasive characteristics of soils and their influence on the wear of various materials which may be used in the construction of tillage tools, tires, or tracks.
- Develop methods to determine basic measures which characterize the strength, reactions, and conditions of soils to be used in conjunction with soil-implement relationships and in describing soil tilth.
- Develop a theory of soil-machine mechanics which will permit the prediction of the soil reaction to tillage tools of given designs or the tractive/transport capacity of a device from a knowledge of the requisite soil and machine parameters.
- Define the soil physical characteristics of an adequate seedbed and rootbed for specific crops. Define the requirements which determine the need for tilling a soil and when tillage is adequate.

Cooperative Work

In its research program, the Laboratory cooperates with and assists other agencies interested in tillage and traction, or otherwise concerned with the soil.

There is both formal and informal cooperation with State agricultural experiment stations, other Federal research agencies, private industry, and research establishments in foreign countries.

From the beginning, studies have been carried out in cooperation with the Agricultural Engineering Department, and the Agronomy and Soils Department of Auburn University. Cooperative work has been done on experiment station farms in a number of other States, including Georgia, Mississippi, Texas, Iowa, and Oregon.

The Laboratory has cooperated with many companies in private industry concerned with the development and manufacture of tillage and traction equipment. Cooperative studies have been made with manufacturers of such equipment as plows, rotary tillers, coulters, sub-soilers, disk-harrow blades, cultivator sweeps, planters, traction tires, and crawler tractor tracks. In many of these studies fundamental data are obtained that are included in technical papers published in professional journals. In practically all studies, the cooperating companies obtain data that enable them to better serve the Nation's agricultural producers.

Cooperation with private industry is limited to the development of basic information that is useful over extensive areas and beneficial to the entire industry concerned. Companies often furnish equipment for the basic studies, and sometimes special instrumentation. Engineers from the companies work with the staff of the Laboratory in planning and carrying out studies.

In addition to an active cooperation program, the Laboratory staff confers, discusses, and, when possible, advises individuals and groups on problems relating to tillage, traction, and transport.

An organization interested in cooperative studies with the Laboratory should write to the Director of the Laboratory, stating the area of interest.

Graduate Study Thesis Problems

The facilities and staff of the Laboratory are available for use by, and to help guide, graduate and advanced graduate students in thesis problems related to tillage and traction. Cooperative agreements may be made with any college or university to enable the graduate student to do part or all of his research work at the Laboratory.

FACILITIES AND EQUIPMENT

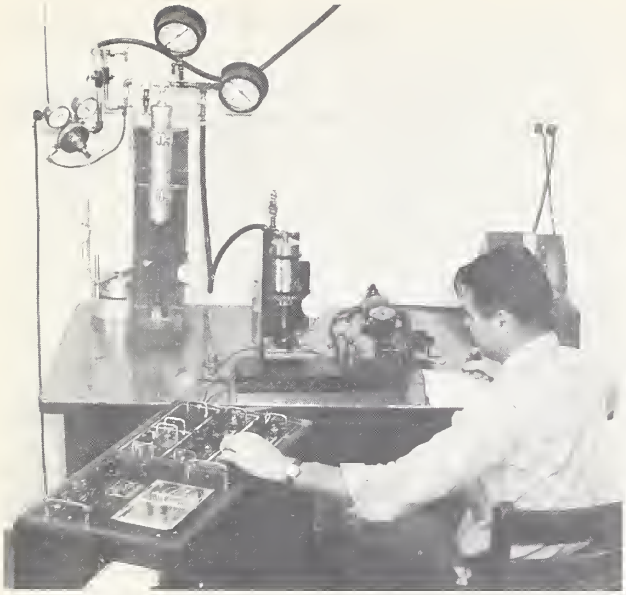
Full-Scale Soil Bins

The Laboratory maintains nine outdoor and two indoor soil bins that contain surface soils selected for making full-scale studies of soil-implement relationships.

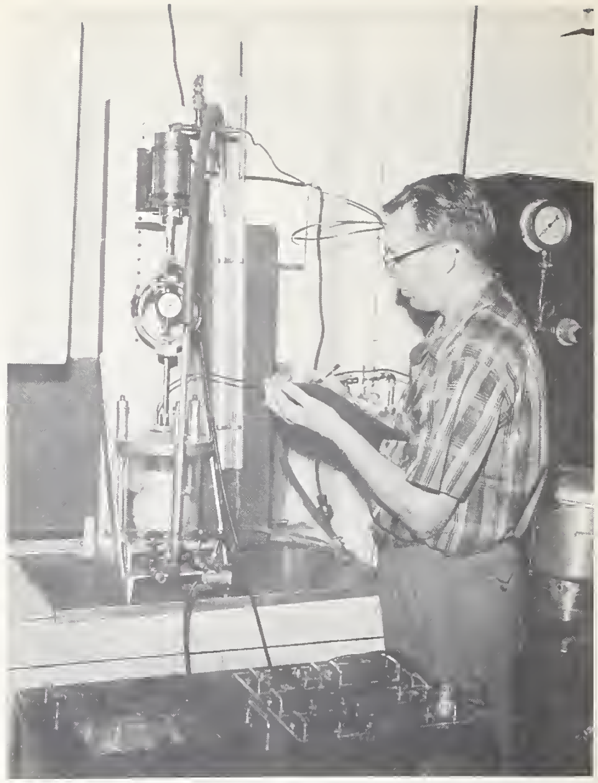
Each outdoor bin is 250 feet long, 20 feet wide, and either 2 or 5 feet deep. The bins are separated by concrete walls, and at the end of each bin there is a concrete apron for assembling equipment to be used in the studies. A steel rail is mounted on the top of each separating wall. Specially designed cars used in testing tillage tools, tires, and tracks run on these rails. During a study, only the tillage tool or traction device being investigated comes in contact with the soil.

Cover cars are used to cover any one bin to prevent weather conditions from changing the physical condition of the soil until a test can be completed. The cars protect the soil from rain or retard drying by the sun.

The two indoor bins are 190 feet long, 20 feet wide, and 5 feet deep, and have a pair of rails for each bin. The same cars operate on the outdoor and indoor bins.

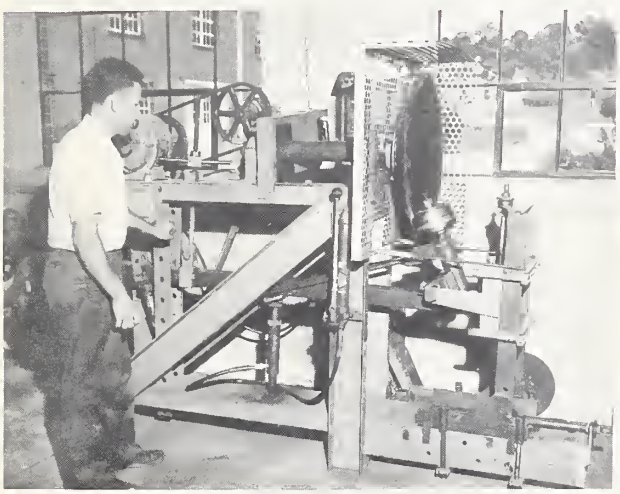


This direct shear machine is used to measure shear values of soil samples. Shear strength must be considered in order to predict the force required to draw tillage tools through soil, or the amount of traction that can be developed by wheels and tracks. (NTML photo-10,110a)



N-28,678

With this tri-axial shear apparatus, controlled forces can be applied to all sides of soil samples during shear studies.



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In this fatigue test, forces up to 2,000 pounds are applied to the edge of a rotating disk to determine fatigue resistance of steel composition, heat treatments, methods of rolling steel, and methods of forming. Equipment can be used also to determine effects of disk thickness, bolt hole arrangement and size, and other factors on strength of mounting.

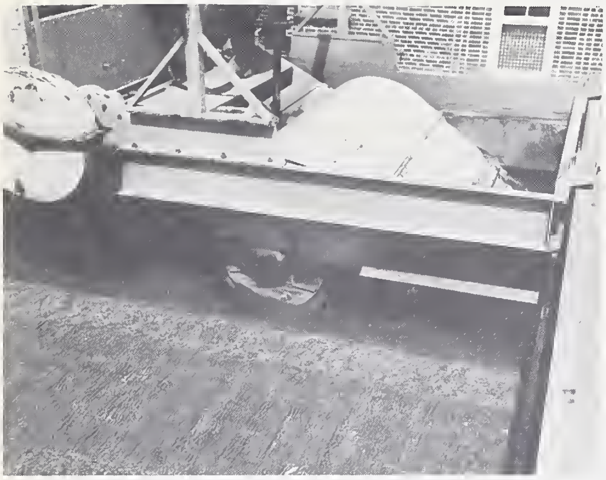
The Soils

The soils in the bins were selected to give a broad variation in soil characteristics. They range in texture from high sand contents to high clay contents. The soils have physical properties representative of a wide range of soils found throughout the United States. A report on most of the physical characteristics of the bin soils, as well as the mineralogical analyses, is available to interested scientists.

Equipment To Measure Soil Forces on Tillage Tools

A power car furnishes power for pulling the tillage tools under study. It can be operated at speeds varying from 0.2 to 10 miles per hour. An implement carrier, equipped with an

Soil-fitting Equipment



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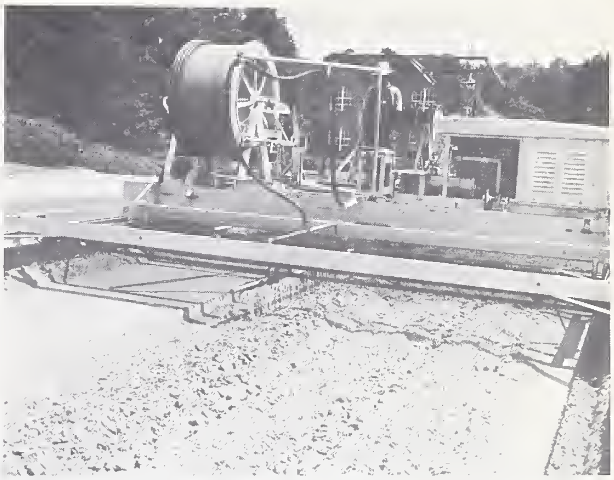
Prior to tillage or traction studies, soil is loosened and broken up with a rotary tiller.



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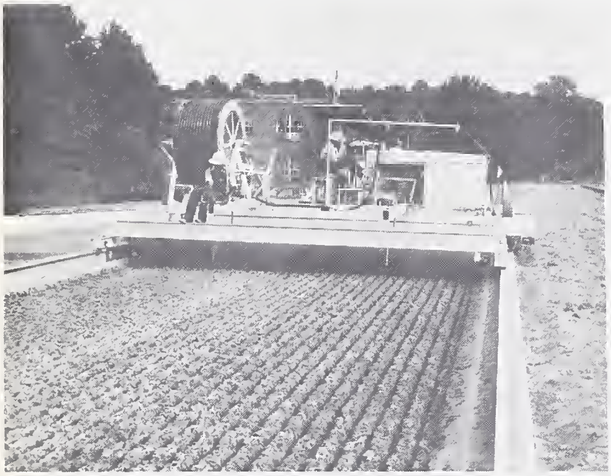
Special watering unit is used to moisten dry soils during soil-fitting operations.



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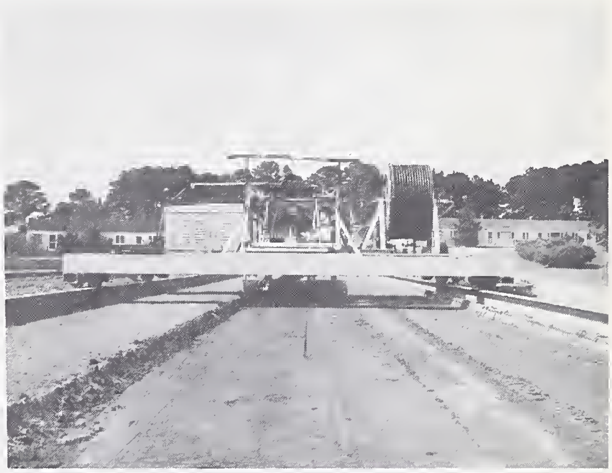
V-shaped packing wheels are used to pack subsoil into a dense condition.



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A leveling blade is used to move soil in the bins or to establish a surface configuration.

electrical resistance strain gage dynamometer, is operated with the power car. The dynamometer is constructed to measure the draft force, the side force, and the vertical force which the soil applies to the tillage tool and the three moments associated with the three forces. It will also measure drawbar loads to 20,000 pounds.

A generator on the tool carrier frame, which runs in contact with the rail, gives an electrical signal proportional to the speed at which the tool is operated. When the angle of operation of the tool is desired, as in disk studies, an electrical signal is generated proportional to the disk angle. Adaptations can be made to measure a varying width or depth of cut.

All of the electrical signals, which represent forces, speeds, or angles, can be recorded on an 8-channel recording oscillograph

or an 8-channel magnetic tape recorder, or both. Any two variables can also be plotted with respect to one another on X-Y recorders. The electrical signals can also be transmitted to an analog computer for on-line computation of desired parameters.

Various dynamometer arrangements can be made to measure the force on the whole tool, on component parts of one tool, or on a combination of tools.

Equipment for Studying Actions of Tires and Tracks

A special car has been developed for studying the performance of traction devices, and the effect of traction devices on soil reactions, such as soil compaction. Measurements are made on a single tire or other traction device. The five basic measurements made are: (1) dynamic load on the tire throughout the operation, (2) the force required to turn the tire (torque), (3) the amount of pull that the tire develops, (4) the amount that the tire slips during the operation, and (5) forward speed. The tire test will accommodate tires 68 inches in overall diameter and will carry a maximum load of 5,000 pounds. The track test unit was designed to carry a maximum load of 10,000 pounds. The basic data are measured by means of electrical analog signals, which are all recorded. Any combination of signals can be transmitted to the analog computer and the signal integrated, multiplied, divided, added, or subtracted. These calculated signals can then be put back on the oscillograph, on the tape recorder, or on X-Y plotters. In all studies, one parameter is changed slowly and continuously throughout the study, and the resulting parameters are measured. In the case of tires, the slip is usually varied from 0 to near 100 percent, and the resulting torque input, pull, and weight transfer recorded. Studies are normally made in a range of soils and soil conditions which approximate the anticipated service conditions, and on concrete.

N-28,704

Stress cells are placed in the soil in various positions to determine the distribution of stresses capable of causing soil compaction.

Soil-Fitting Equipment

The soil properties that are controlled in studies are the degree of compaction, moisture content, and degree of pulverization. Several pieces of equipment are available for preparing the soil. A self-propelled car, which runs on the bin rails, operates a leveling blade used to control the level of the soil surface. This unit also operates a cross-watering unit which is used to add moisture to a soil when desired. The self-propelled car may be fitted with a gang of V-shaped packers to pack the soil subsurface, or a flat roller to pack the surface. A special rotary tiller is available to pulverize the soil and leave it in a loose condition. Since the tillage tools and traction devices are run lengthwise in the bins, a cross tiller is used to stir the soil across the bins to help remove lengthwise streaks.

Small Bin Facilities

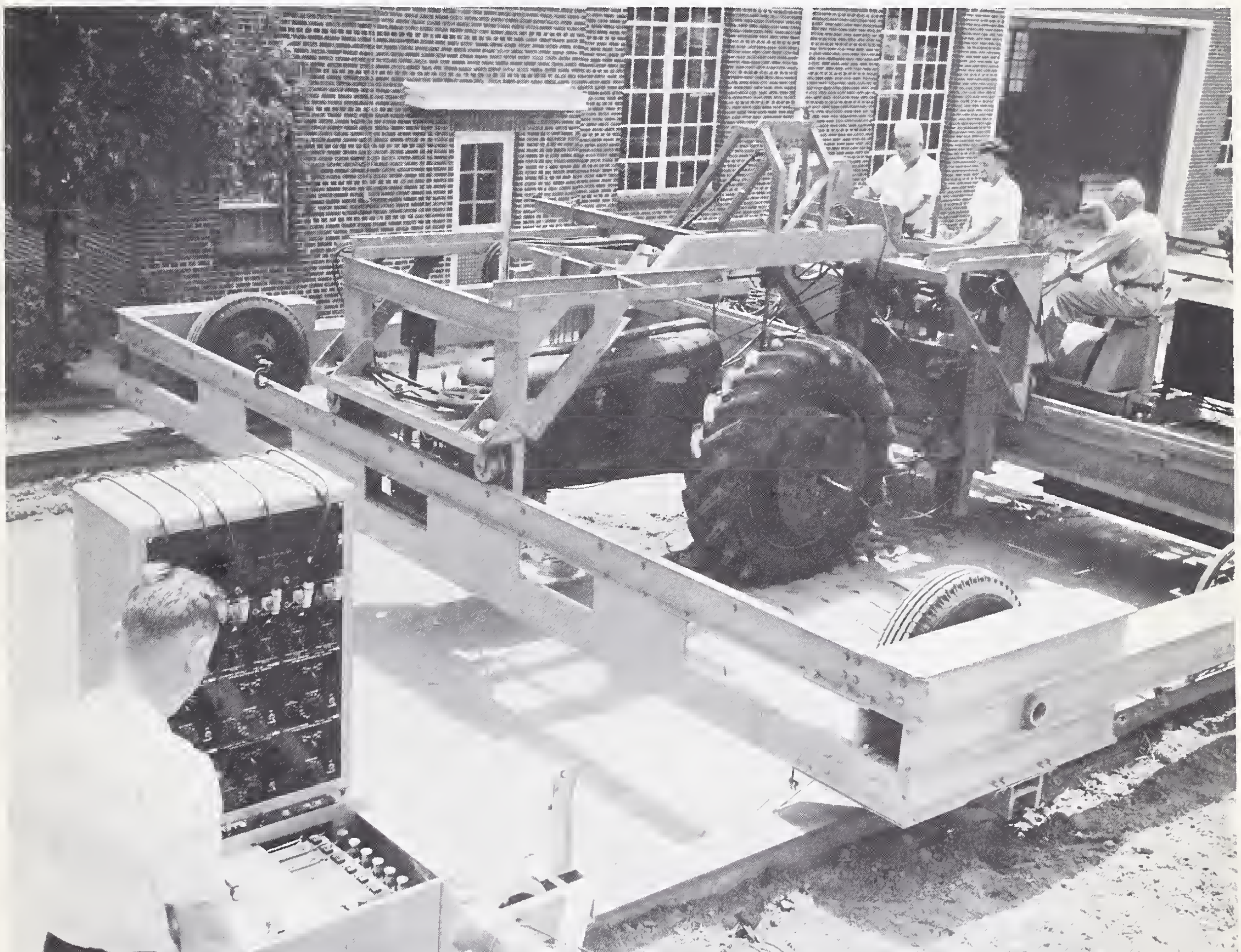
Small soil bins located indoors are used to expedite certain soil-implement relationship studies. One bin is 18 inches wide, 12 inches

deep, and 60 inches long. Another, which is 12 inches wide, can be equipped with a glass side for observing soil movement resulting from the operation of tillage tools.

A circular soil bin used to study small tools and model tools is 2 feet wide and 12 inches deep, with an outside diameter of 18 feet. It is driven with a hydraulic motor so that speeds can be programed. The circular bin is equipped with a rotary tiller to pulverize the soil, a flat roller to compress the soil, a watering device to increase the soil moisture content, and a tool carrier with a dynamometer that will measure forces in three directions and the associated moments.

In all of the small bin facilities, the soil moves and the tool remains stationary. This allows better observation of the soil reaction to the tool.

Small bin facilities are used in carrying out research on scaled models of tools and equipment, as well as small tools and wheels. Both natural and artificial soils are used in the bins. These facilities can also be used to study wear on metals, plastics, and other materials, and for measuring friction and adhesion between soils and materials.



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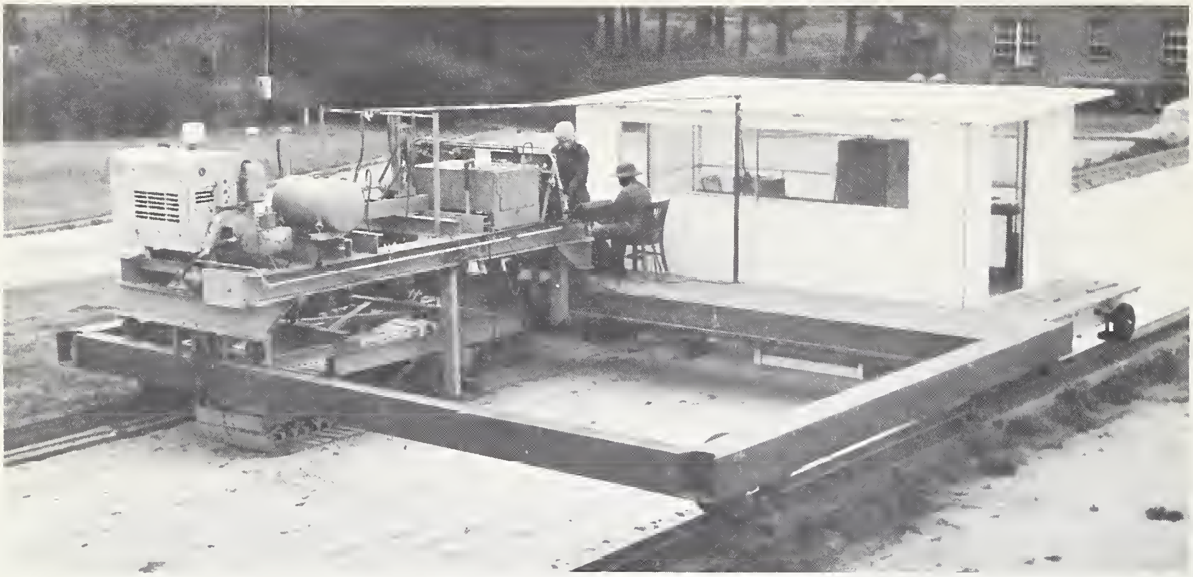
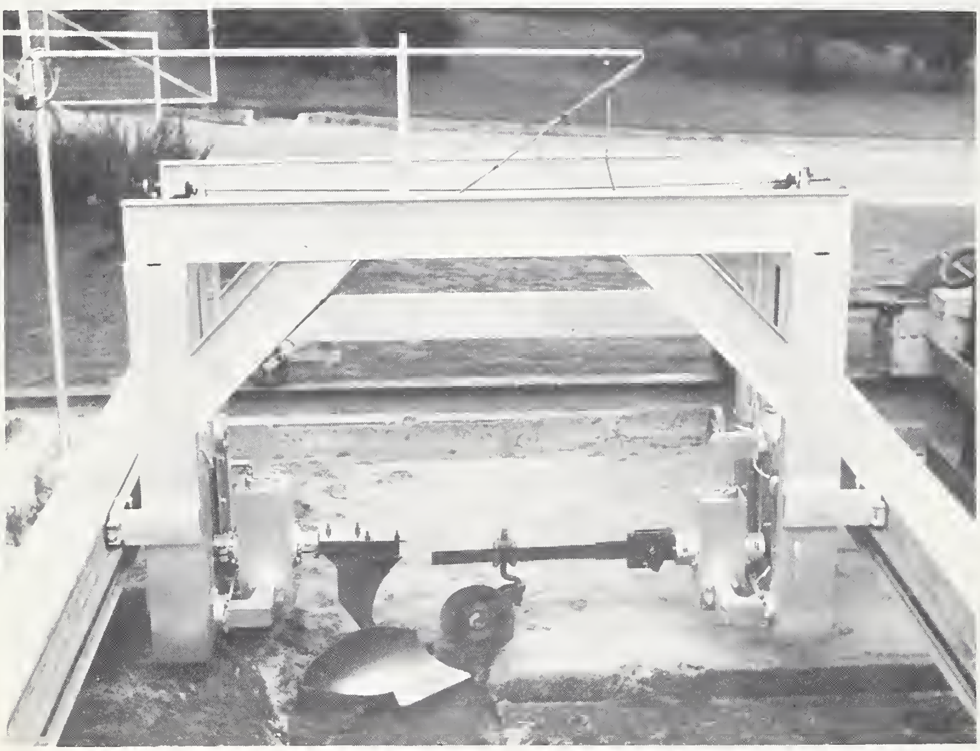
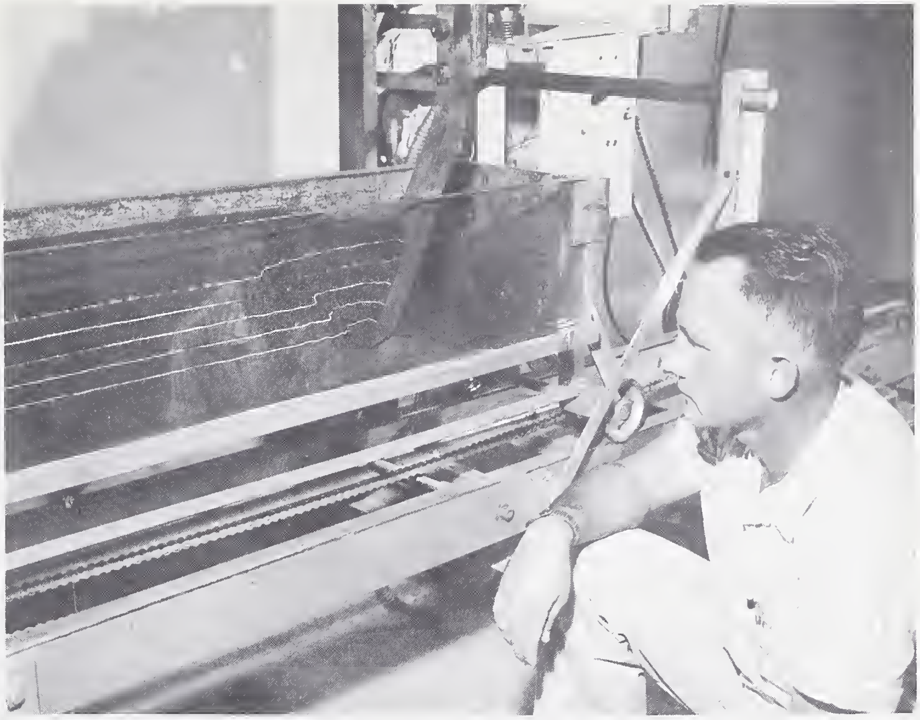
Oscillograph in foreground records stress being detected by cells in the soil as soil is loaded by tractor wheel. Forces applied to the soil by traction-measurement unit are also continuously measured.



Track test unit with instrument car. Torque input, drawbar pull, track speed, car speed, and weight on track are measured. The instrument car carries the recording oscillograph, analog computer, tape recorder, and X-Y recorders. The instrument car is also used with the tire and tillage tool test units. (NTML Photo M10, 196m).



Tillage tool test car. Two dynamometers each capable of measuring forces in three planes and their associated moments make it possible to measure soil reaction forces on two components of a tillage tool simultaneously. (NTML Photo M10,201a).



N-28,698

The glass side in this soil bin makes it possible to observe the reactions of soil as it moves against an inclined chisel mounted in a fixed position. The white lines (soft tissue paper) indicate the soil reaction.

Laboratory Facilities

Laboratories and equipment are available for studying physical and mechanical properties of soil. In tillage and traction studies, shear machines, tension apparatus, and beam testers are used for measuring the strength of the soil.

Soil reactions to programed mechanical forces can be measured, as well as soil parameters which may be used to characterize the soil. A controlled environment chamber is available for studying the soil parameters which can be changed by tillage tools. In this chamber the temperature, humidity, and light intensity can be controlled.

The resistance of metals, plastics, and other materials to abrasion can be studied, as well as the ability of materials to resist soil sticking. Impact and fatigue test equipment is available for determining the strength of disks; also equipment for measuring the geometry of tillage tools.

Field Facilities

A 100-acre farm containing clay soils and a 370-acre farm containing sandy soils, which belong to the Agricultural Engineering Department of Auburn University, are available for field studies. Experiment station farms of other cooperating States are also available. At times, measurements of such factors as soil force reactions to tools, and wear resistance of materials, are made on private farms.

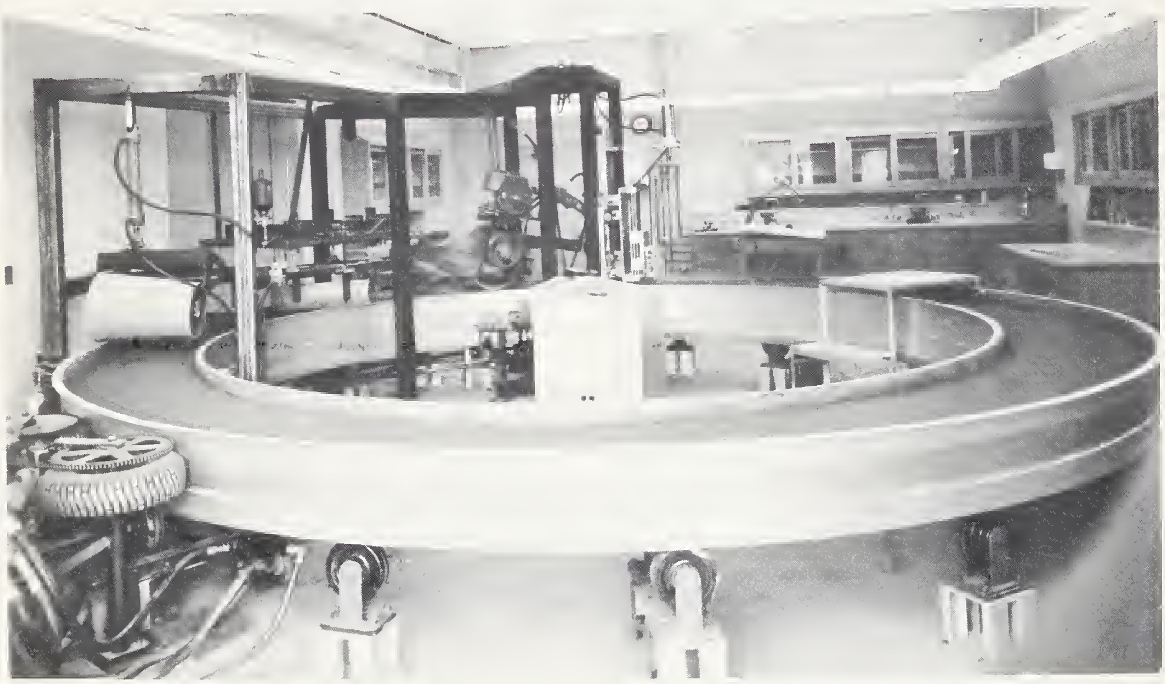
PUBLICATIONS

A list of technical publications resulting from the research work at the Laboratory can be obtained from the National Tillage Machinery Laboratory, P. O. Box 792, Auburn, Ala., 36830, or Agricultural Engineering Research Division, Agricultural Research Service, U.S. Department of Agriculture, Plant Industry Station, Beltsville, Md., 20705.

The publications are an important contribution to scientific literature on tillage and traction equipment and related phases of soil science. In many cases they report the results of cooperative studies with private industry.

Some of the publications are dated before 1935, when the Laboratory was established. They report results of research by agricultural engineers of the Alabama Agricultural Experiment Station. The results of this research led to a cooperative project with the United States Department of Agriculture, which in turn influenced the establishment of the Laboratory.

The research information reported is for the most part technical, and prepared for use by engineers and soil scientists. Some of the materials, however, is suitable for direct use by farmers and ranchers.



Small tools and model studies may be conducted in this circular soil bin where the soil moves and the tool remains stationary. (NTML Photo M10, 188p)

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